Annex C
The Japanese case study: Empirical specification

The detailed modelling specifications for Japanese case study are provided in this Annex.

Profit function

Farmer's profits from production in the absence of government intervention are

$$\pi^i = p_i y_i - c x_i - w_i n_i - o_i \quad for\ i = 1,2 \tag{19}$$

where p_i refer to the price of crops, y_i to the yield/10 ares, c to the fertilizer (nitrogen) price, w_i to wage rate per hour and o_i to other cost. The model employs a quadratic Nitrogen response function, $y_i = a_i + \alpha_i x_i + \beta_i x_i^2$ where x_i refer to the amount of N application (kg/10 ares). They are estimated for crop 1 (rice) and crop 2 (wheat).

When famers consider (to use) organic matter application x_{oi} in addition to (instead of) chemical N fertilizer x_{ci}, total amount of N application to the agricultural field is summation of N fertilizer and N content of organic matter. Despite recommend organic matter application amount (*e.g.* 1.0-1.5 t/10 ares for paddy field), the implementation is inactive (88 kg/10 ares) due to the following problems.

- Difficulties to realise of the manure application effects from farmers' viewpoints due to the diverseness of manure quality;
- Huge amount of application is needed comparing with chemical (high spreading cost);
- Lack of co-operation among crop and livestock farming (high transportation cost).

Several surveys have already revealed that the effect of organic matter application to the yield is statistically positive. According to Shibahara *et al.* (1999), continuous long-term application of organic matter retrench the total N application for the certain amount of the yield due to the high N absorption of organic matter. In fact, according to the answers for the mail survey by the Livestock Environmental Improvement Organisation in 2003, the reason for the organic matter applications for farmers were improvement of the quality of products or stabilisation of production *via* keeping fertility of soils, keeping the soil soft and activate soil microbe.

Average N content in organic fertilizer (cow manure) is set as 0.7% based on Okayama prefecture agricultural centre (2008, originally from MAFF), and then total amount of N application is expressed as

$$x_i = x_{ci} + 1000 \bullet x_{oi} \bullet 0.007 \qquad (20)$$

1 000 means the conversion of unit from tonne to kg.

Generally, N requirement *substitution rate (%) = the amount of organic fertilizer (kg/10a)* N content rate (%)*Fertilizer efficiency (%), where fertilizer efficiency is 30% (Okayama prefecture agricultural centre, 2008, originally in Nishio, 2007).

Suppose that positive effect for yield is expressed as $\Phi_i(x_{oi})$, and that of paddy is supposed as 5% and wheat is as 10% under the 1t application, which is based on the several field survey data (*e.g.* Miyazaki prefecture, 1999; Shibahara *et al.*, 1999). Taking into consideration of additional cost for organic matter application, profits function is expressed as follows:

$$\pi^i = p_i(a_i + \alpha_i x_i + \beta_i x_i^2)\Phi_i(x_{oi}) - cx_{ci} - (c_{op} + c_{ot} + c_{os})x_{oi} - w_i n_i - o_i \quad for\ i = 1,2 \qquad (21)$$

where c_{op} refer to the price of organic matter (JPY/tonne), c_{ot} to transportation cost (JPY/tonne) and c_{os} to the spreading cost (JPY/tonne).

Nitrogen response function

Rice paddy

Quadratic nitrogen response function of rice paddy was estimated by over 50 sample field surveys data which was collected by Toriyama (2000):

$$y_1 = 368.6 + 31.7x_1 - 1.4x_1^2 (R^2 = 0.61) \qquad (22)$$

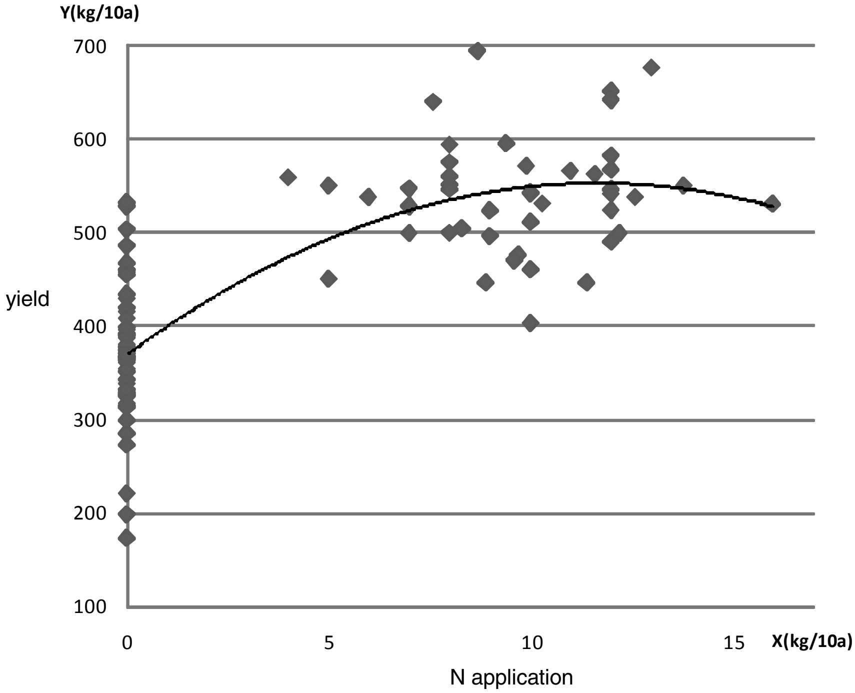
Even if without fertilizer, nutrition in the irrigation water affects to yield. It is generally said that the yield without fertilizer decrease only 1/5 due to the high fertility of paddy.[1] To reflect actual yield in paddy field, a_i is given by fixed value to exclude the effect of the irrigation water, and then the land quality q is incorporated into the response function. Response function is expressed as

$$y_1 = 368.6 + (e_0 + e_1 q)x_1 - (\mu_0 + \mu_1 q)x_1^2 \qquad (23)$$

According to data in Toriyama (2000), spread of yield is about 30% under the average N application amount (see Figure C.1). Consequently, the ranges of parameters are set as $22.19 \le e_0 + e_1 q \le 41.21$ *and* $0.98 \le \mu_0 + \mu_1 q \le 1.82$. When q is distributed uniformly between 1 to 60, parameters e_0, e_1, μ_0 and μ_1 are estimated as follows:

$$e_0 = 22.868, e_1 = 0.322, \ \mu_0 = 0.994 \text{ and } \mu_1 = 0.014$$

Figure C.1. The relationship between nitrogen application and yield for rice



Source: Toriyama (2000).

Wheat

Quadratic nitrogen response function of wheat (converted from rice cultivation) was estimated by National Agricultural Centre data sets (1989):

$$y_2 = 214.9 + 45.6x_2 - 1.2x_2^{\,2} (R^2 = 0.99) \tag{24}$$

However, this survey was undertaken to collect the highest yield data. Therefore the function (24) could not be a representative average response function. Due to the lack of enough data to reflect land quality variety, average and lowest yield response function are estimated based on the assumption that spread of yields is about 40 %. This 40% is based on the variety of targeted yield under the average N application, which is determined in *The Nitrogen Application Standard* by each local government.

Wheat response function to nitrogen is expressed as

$$y_2 = 214.9 + (h_0 + h_1 q)x_2 + (\eta_0 + \eta_1 q)x_2^{\,2} \tag{25}$$

where $19.54 \le h_0 + h_1 q \le 45.6$ *and* $0.51 \le \eta_0 + \eta_1 q \le 1.2$.

Then, the following parameter s are obtained, $h_0 = 19.101$, $h_1 = 0.442$, $\eta_0 = 0.526$ and $\eta_1 = 0.012$

Nitrogen runoff and purification function

Rice paddy

It is difficult to formulate the relationship between the amount of N application and its impact by easy-to-use way, because N runoff from irrigation and meteoric water might affect to N balance in rice paddy. Generally, N runoff from paddy is explained as follows:

[N runoff (surface runoff＋subsurface flow)]＝[The effect of irrigation water-load]＋[The effect of meteoric water-load]+ [The effect of N application].

In this regard, Kunimatsu and Muraoka (1989) proposed that the polluting load L is given by $L = \alpha C_{i1}Q_{i1} + \beta C_{i2}Q_{i2} + \lambda X$, where C_{i1} and C_{i2} are concentration of irrigated water and meteoric water, Q_{i1} and Q_{i2} denote their volume, respectively. X is amount of fertilizer application. α, β and γ are each coefficients. They also said that, meanwhile, the amount of N into the agricultural land from fertilizer is fairly larger than those of irrigated water and meteoric water. Ignoring the effect of two terms $\alpha C_{i1}Q_{i1}$ and $\beta C_{i2}Q_{i2}$, the relational expression is $L = \lambda F$. Taking into consideration of the large effect of fertilizer application as stated in Kunimatsu and Muraoka (1989) and conveniences for economic optimization, the Secretariat tried to estimate the relationship between N application and runoff by exponential form (*e.g.* Tabuchi and Takamura, 1985) as:

$$z_i = \chi_i \exp(\delta_i x_i) \qquad (26)$$

where z_i refer to the amount of N runoff (surface and subsurface) and x_i to the amount of N application.

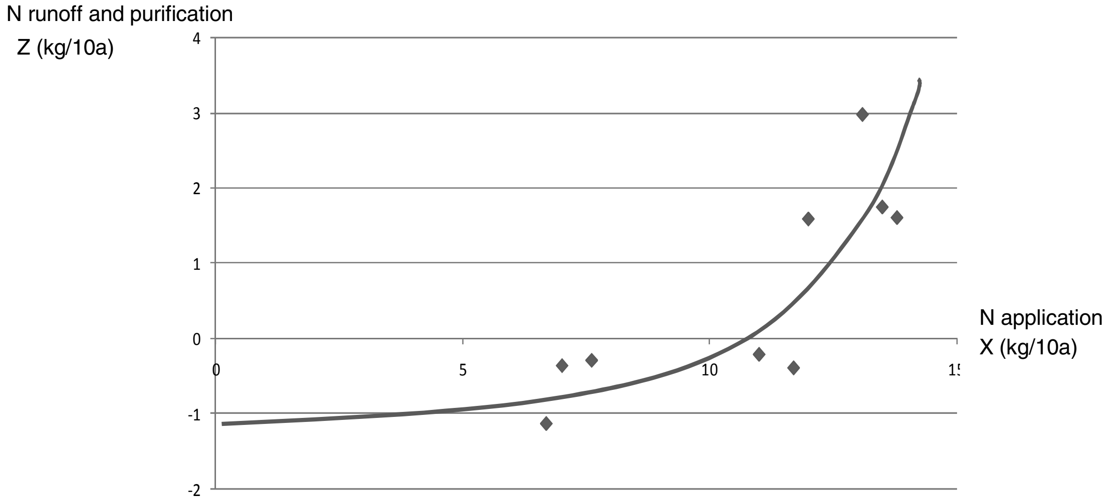
Paddy fields could be N removal sites or pollution sites depending on agricultural activities and nitrogen concentration of irrigation water. It is well known that paddy fields and wetlands effectively improve water quality by removing nitrogen due to denitrification and absorption, which is effective only when irrigation water has strong concentration. Although the nitrogen movement in paddy is not simple, relationship was estimated by using Kunimatsu and Muraoka (1989) and recent field survey data which were collected by Shiga prefecture during paddy cultivation period (Figure C.2). Exponential relation was found between the amount of N application and runoff.

$$z_1 = 0.0062e^{0.465x_1} - 1.14 (R^2 = 0.54) \qquad (27)$$

where z_1 refer to the amount of N runoff from paddy and x_1 to the amount of N application in paddy.[2]

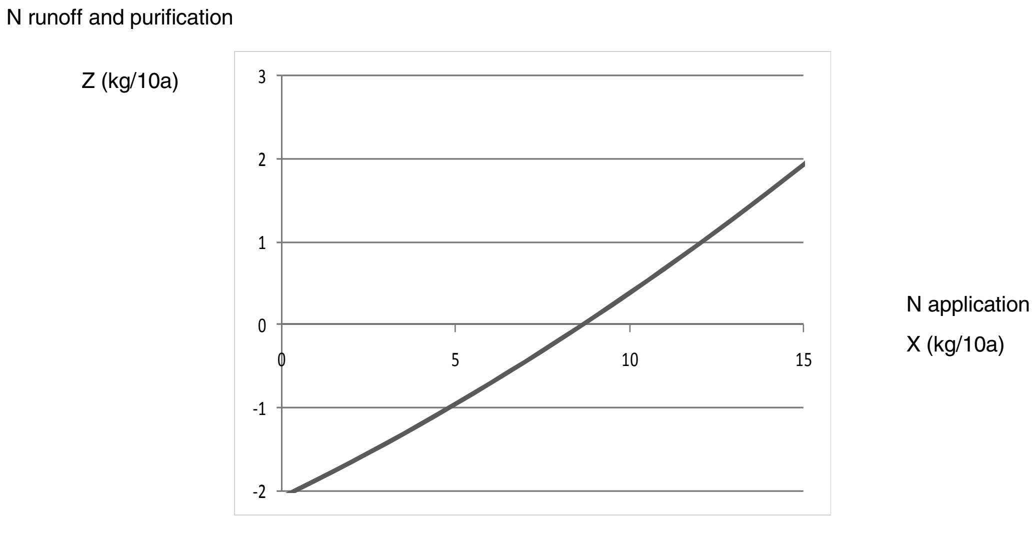
The number of observations is not enough to examine the validity and also R^2 is not so high to obtain the robust results. At this point, another curve was estimated by different approach based on N balance in paddy field: [Net N runoff (kg/10a)] = 0.0042 × [N applied (kg/10 a)]^2 + 0.2049 [N applied (kg/10 a)] – 2.0858,[3] which is shown in Figure C.3. As shown, the overall shape is not similar to Figure C.2. However, in the limited range for general N application in paddy field (5-10kg/10 a), the differences between those of two curve is not particularly large.

Figure C.2. Field data on N runoff and purification in paddy field



Sources: Kunimatsu and Muraoka (1989) and Shiga prefecture (2007).

Figure C.3. N runoff and purification curve alternative estimation



Source: Author's calculations.

Wheat

In a precise sense, soil condition, crops, cropping season and methodological condition could affect to N runoff, nevertheless approximately 30% of applied N could runoff as the average in Japanese condition (Kunimatusu, 1989; Takedam 1997; Shiratani, 2004).[4] But linear function is not appropriate for optimisation of the social welfare function. Consequently, exponential form was estimated on the basis of Japanese field data which was sorted out by National Institute for Ago-Environmental Science (NIAES),

$$z_2 = 1.129e^{0.114x_2} (R^2 = 0.19) \quad (28)$$

where z_2 refer to the amount of N runoff and x_2 to the N application.

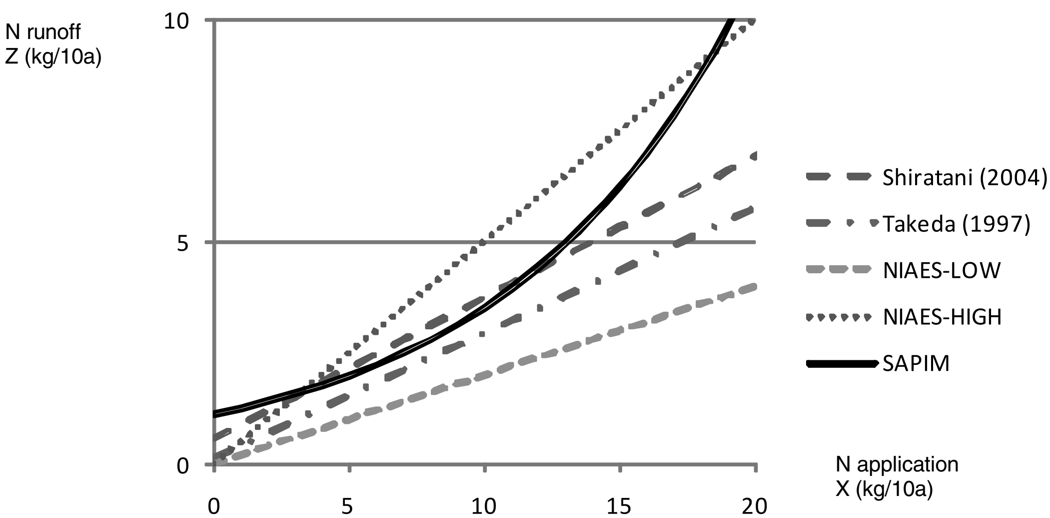
Due to the lack of enough observation (there is no information on slopes), R^2 is not sufficiently high. To verify the robustness of estimated exponential curve, the linear functions and general nitrogen runoff ratio (Table C.1) were compared in Figure C.4. Under the average amount of N application, say lower than 20 kg/10a, there is consistency with the other estimation results as shown in Figure C.4.

Table C.1. Nitrogen runoff ratio

Pollution source	Land use	N runoff ratio (%)
Fertilizer application	Paddy field	0-10
	Upland field	20-50
	Grassland	5-20
Manure	Livestock farm	60-100

Source: National Institute for Agro-environmental Science (1998).

Figure C.4. Estimated nitrogen runoff function form in upland field



Source: Author's calculations.

GHG emission and sequestration function[5]

Each category of emissions are considered here one by one based on the IPCC (2006), MOE (2008) and field survey data for country specific coefficients.

CH_4 emission

Rice paddy

It is well known that rice cultivation is a main anthropogenic source of CH_4 emissions. According to the IPCC (2006), several rice cultivation characteristics should be considered in calculating CH_4 emissions: regional differences in rice cropping practices, multiple crops, water regime, ecosystem type, flooding pattern etc. In addition to these factors, the impact of organic amendments on CH_4 emissions is huge, and amount of the applied material and CH_4 emission can be described by a response curve. Yan *et al*. (2005) conclude that organic amendment and water regime in the rice-growing season were top two control variables, and climate was the least critical variable.

The water regime in the rice growing season was classified as: continuous flooding, single drainage, multiple drainage, wet season rain fed, dry season rain fed, deepwater, or unknown. In Japan, most of paddy fields (98%) are intermittently flooded. There is scaling factor for water regimes during the cultivation period relative to continuous flooded field, however, intermittently flooded (multi aeration) in the IPCC category is different in nature from the intermittently flooded paddy field (single aeration) concept in the IPCC Guideline.[6]

IPCC (2006) set a default seasonal CH_4 emission factor for rice *under continuous flooding conditions and without organic matters*. Scaling factors (SF) are used to estimate CH_4 emissions from rice fields to reflect each countries situation such as water regimes or organic matters. But IPCC (2006) said that country-specific emission factors and scaling factors should only be used to reflect appropriate condition if they are based on well-researched and documented measurement data (IPCC, 2006). A default emission factor is 1.30 kg CH_4/ha/day (23.4 kg/10a/180 days).

The basic equation to estimate CH_4 emission from rice cultivation per 10a is defined in equation (29), which is converted form IPCC (2006).

$$CH_4 = EF_c \bullet SF_w \bullet SF_p \bullet SF_o. \tag{29}$$

where, CH_4 (t CH_4/10a/yr) is annual CH_4 emissions from rice cultivation, EFc is the baseline emission factor for continuously flooded fields without organic amendments, SFw is the scaling factor to account for the differences in water regime during the cultivation period, SFp is the scaling factor to account for the differences in water regime in the pre-season before the cultivation period and SFo is the scaling factor to account for the differences in both type and amount of organic fertilizer applied.

As for emission factors, Japan has country-specific emission factors for intermittently flooded paddy (single aeration), which has estimated as 12.96 $gCH_4/m^2/yr$ (0.001296 tCH_4/10a/yr) in MOE (2008).[7] This data reflects both of Japanese specific emission factors and water regimes.

The scaling factor of organic fertilizer is defined as follows (IPCC, 2006):

$$SF_0 = \left(1 + \sum_j x_{oj} \bullet CF_j \bullet 10\right)^{0.59} . ^8 \tag{30}$$

where x_{oj} (t /10a) is application amount of organic fertilizer j in dry weight for straw and fresh weight for others, CF_j is conversion factor for organic fertilizer j (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in Table C.2.

As shown in Table C.2 and Figure C.5, the impacts of organic fertilizer are much differing in their types and application amount. On present showing that rice straw is applied in 60% of agricultural land, the other manure is in 20% and no application is 20% (MOE, 2008) in Japan, otherwise MAFF is strongly promoting the manure application from the perspective of (net) GHG reduction and keeping fertility of the soil. The conversion factor of farm yard manure is, therefore, going to be used in this modelling. This choice of control variable is also important at the policy simulation stage, because manure application takes further effort for manure collection and spreading (Japan Soil Association, 2009).

By using country-specific data, CH_4 emission (t CH_4/10a/yr) equations (15) are re-written as follows:

$$CH_4 = 0.001296 \bullet \left(1 + x_o \bullet 0.14\right)^{0.59} . \tag{31}$$

The Guidelines for Enhancement Fertility of Soil recommend that normal manure application amount is 1.0-1.5t/10a in paddy, but the actual application is decreasing from 451 kg/10a (y1970) to only 88 kg/10a (y2005) due to decoupling of crop and livestock farming and aging of farm labour forces.

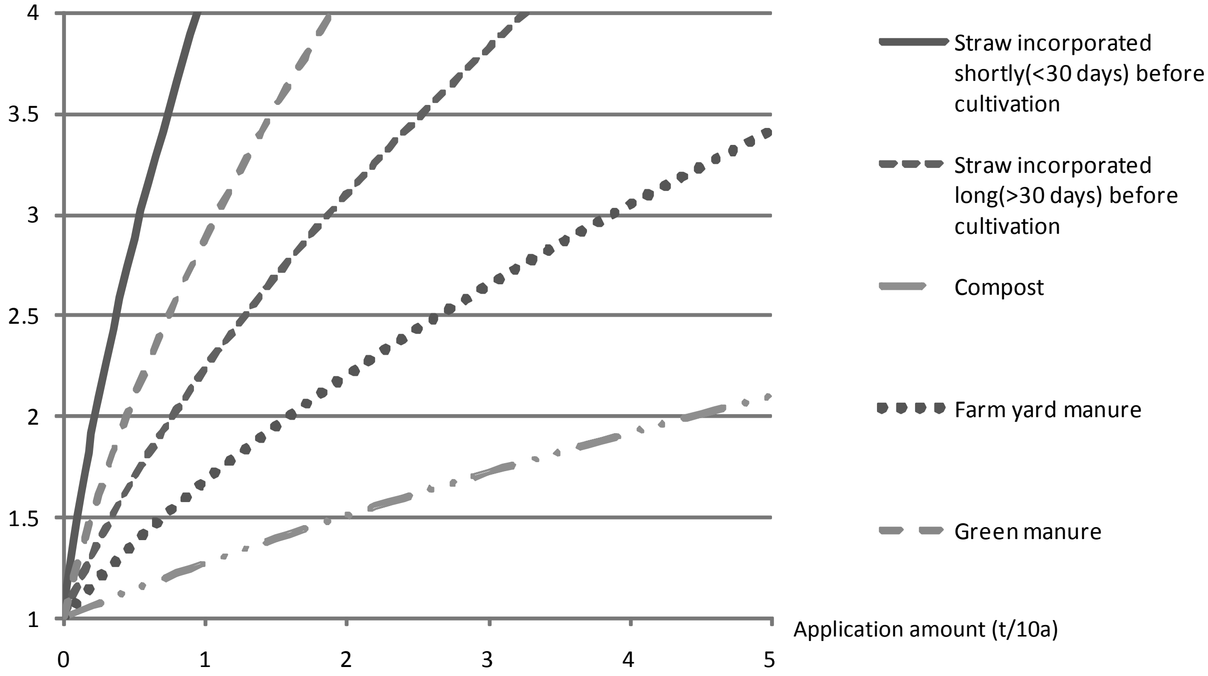
Table C.2. Default conversion factor for different types of organic amendment*

Organic amendment	Conversion factor (CF_i)	Error range
Straw incorporated shortly (<30 days) before cultivation	1	0.97-1.04
Straw incorporated long (>30 days) before cultivation	0.29	0.20-0.40
Compost	0.05	0.01-0.08
Farmyard manure	**0.14**	**0.07-0.20**
Green manure	0.50	0.30-0.60

* Straw is in dry weight, but others are in fresh weight.

Sources: Yan *et al.* (2005); IPCC (2006).

Figure C.5. The relationship between the amount of organic amendment application and the size of conversion factor



Sources: Yan *et al.* (2005); IPCC (2006).

Upland

Methane generation is not possible, if soil is not maintained in an anaerobic state. Upland soils are normally oxidative and in aerobic condition, therefore CH_4 is not produced.

N_2O emission

Direct emission

The fertilizer application and ploughing of organic soil cause ammonium ions inside the soil, and then N_2O is emitted in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. In addition, N_2O is emitted *via* denitrification. EFs for N_2O associated with the application of synthetic fertilizers to farmland soil were set based on actual data conducted in Japan, and same emission factors are also used for those of organic fertilizer. Because there was no the significant differences between EFs of synthetic fertilizers and organic fertilizers, analysing data on N_2O emissions from Japanese agricultural fields. Akiyama *et al*. (2006) estimated EFs of Japanese rice paddies and upland fields as **0.31**% (±0.31%) and **0.62%** (±0.48%), respectively. Uncertainties still remain, but these EFs are used in MOE (2008),[9] as shown in Table C.3.

Fertilizer application derived N_2O emission is,

$$N_2O_{direct\_i} = \frac{1}{1000} \bullet EF_{di} \bullet (x_{ci} + x_{oi} \bullet 0.007 \bullet 1000) \bullet \frac{44}{28}. \qquad (32)$$

where $N_2O_{direct\_i}$ refer to direct N_2O emissions derived from fertilizer application in land use i (t N_2O), EF_{di} to emission factors (kgN_2O-N/kgN) (for paddy: 0.0031 and for upland crop: 0.0062), x_{ci} to the amount of chemical fertilizer application (kgN), x_{oi} to application amount of organic fertilizer (tonnes/10a) and 44/28 means the conversion of N_2O-N emission to N_2O emission.

Indirect emission

In the next step, the estimation methods of indirect emission are going to be considered. When E_{adi} is N_2O emissions associated with atmospheric deposition (kgN_2O) and E_{li} is emissions associated nitrogen leaching and runoff (kgN_2O), indirect emission $N_2O_{indirect\_i}$ is expressed as follows:

$$N_2O_{indirect\_i} = E_{adi} + E_{li}. \qquad (33)$$

Emissions from atmospheric deposition can be expressed as,

$$E_{adi} = EF_{ad} \bullet (x_i \bullet Frac_{GASF} + N_D \bullet Frac_{GASM}) \bullet \frac{44}{28}. \qquad (34)$$

where E_{ad} refer to N_2O emissions from atmospheric deposition, EF_{ad} to emission factors (kgN_2O-N/kgN) , x_{ci} to the amount of nitrogen fertilizer, $Frac_{GASC}$ (0.1) to the rate of deposition chemical fertilizer (kgNH_3-N+NOx-Nkg), N_D to the amount of N in applied organic fertilizer, $Frac_{GASO}$ (0.2) is the rate of deposition from organic fertilizer (kgNH_3-N+NOx-Nkg). Therefore,

$$E_{adi} = \frac{1}{1000} \bullet 0.01 \bullet (x_{oi} \bullet 0.1 + x_{ci} \bullet 0.007 \bullet 1000 \bullet 0.2) \bullet \frac{44}{28}. \qquad (35)$$

Emissions from nitrogen leaching and runoff (E_{li}) are defined by,

$$E_{li} = \frac{1}{1000} \bullet EF_l \bullet z_i \bullet \frac{44}{28} \qquad (36)$$

where EF_l refer to the N_2O emission factor from nitrogen leaching and runoff (kgN_2O) and z_i to the runoff amount (kgN). Although the proportion of N runoff against application is set as 30% in the MOE (2008), equations (13) and (14) which are estimated in this SAPIM analysis are used for the leaching and runoff amount.

$$E_{li} = \frac{1}{1000} \bullet 0.0124 \bullet Z_i(x_i) \bullet \frac{44}{28} \qquad (37)$$

All of the emission factors used this section are summarised in Table C.3.

Table C.3. N_2O emission factors for fertilizer in agricultural soils

	Crop species	Emission factor (kgN_2O-N/kgN)	Uncertainties (kgN_2O-N/kgN)
Synthetic and organic fertilizer	Paddy rice	0.31%	±0.31%
	Upland crop	0.62%	±0.48%
Indirect emission (atmospheric deposition)		1.00%	±0.5%
Indirect emission (nitrogen runoff and leaching)		1.24%	±0.6-2.5%

Source: MOE (2008).

CO_2 emissions and sequestration

As already mentioned, only four countries are elected to include "Cropland Management and Grazing Land Management (the key activities relevant to agricultural industries)" in their accounts for the Kyoto protocol first commitment period, however the relationship between farm management and SOC could be considerable in anticipation of post-Kyoto discussion. Japan has country-specific continuous survey data, which had been undertaken in 52 areas for paddy and 26 are for upland crops. Overall average data reveals that organic matter applications increase the amount of carbon sequestration: 1t /10 ares manure application cause 40.6-77.4 kgC/10 ares sequestration in paddy field and 1.5 t/10 ares manure results 37.3-170.9 kgC/10 ares sequestration in upland.

The amounts of carbon sequestration *via* organic matters application differ from soil type to soil type. In this analysis, gray lowland soils and gley soils for rice paddy and andosols for upland crop are used for curve estimation respectively, because these soil types are one of the representative soils which are widely distributed in Japan, as shown Table C.4. In addition, the use of dominate type soil could permit extrapolation to more spatially aggregate level.

The amount of carbon sequestration is expressed as follows,

$$CO_{2i} = \sum Seq_i \bullet \frac{44}{12} \tag{38}$$

Regarding specification of function form, since there is upper bound for carbon sequestration capacity, polynominal functions are estimated by using data from MAFF which include the amount of application per year, the increased amount of soil carbon in each soil types. And then (39) and (40) are estimated for paddy and upland field, respectively (Figure C.6).

$$Seq_1 = -0.0062x_o^{\ 2} + 0.052x_o \ (R^2 = 0.80) \tag{39}$$

$$Seq_2 = -0.0013x_o^{\ 2} + 0.022x_o . \ (R^2 = 0.69) \tag{40}$$

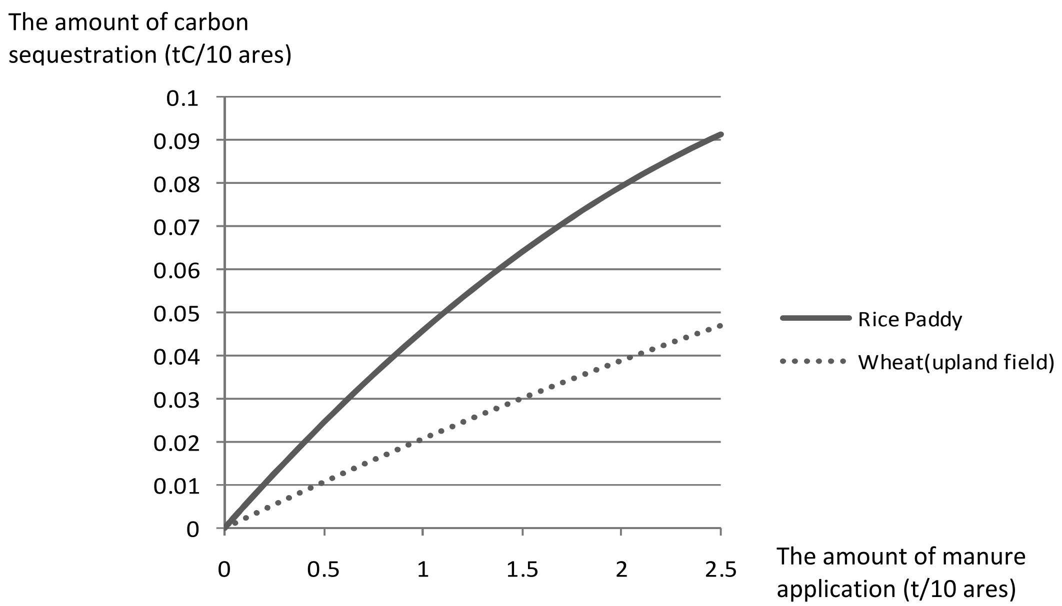
Table C.4. The amount of carbon sequestration in the case of manure application

(1.0 t/10 ares for paddy and 1.5 t/10 ares for upland)

		The amount of carbon sequestration (tC/10 ares/yr) **(A)**	**Area** (1 000 ha) **(B)**	**The amount of carbon sequestration** (1 000 tC/yr) **(A*B)**
Paddy field	***Grey lowland soil***	***0.0472***	***718***	***339***
	Gley soils	***0.0406***	***604***	***245***
	Wet andosoils	0.0774	186	144
	Yellow soils	0.0515	98	50
	Brown lowland soils	0.0752	96	72
	SUM		1 702	850
Upland crop field	***Andosols***	***0.0373***	***1 584***	***591***
	Brown forest soils	0.0644	450	299
	Yellow soils	0.0696	308	214
	Grey lowland soil	0.1709	144	246
	SUM		2 486	1 350
SUM				2 200

Source: MAFF (2008b; 2008c).

Figure C.6. The relationship between the amount of manure application and the amount of carbon sequestration



Source: Author's calculations.

The other parameters for the model are reported in Table C.5.

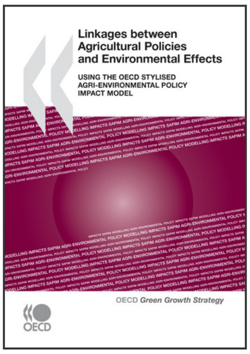
Table C.5. Parameter values in the numerical application

Parameter	Symbol	Value	Unit	Source
Price of crop:			JPY/kg	MAFF stat. (2008)
Rice	P_1	219		13 130 JPY/60kg
Wheat	P_2	152		9 144 JPY/60kg
Price of nitrogen fertilizer	C	183.8	JPY/kg	MAFF stat. (2008)
Labour cost:			JPY/10a	MAFF stat. (2008)
Rice	W_1n_1	26 087		W_1 18.5h/10a, n_1: 1 410 JPY/h
Wheat	W_2n_2	6 699		W_2: 4.4h/10a, n_2: 1 523 JPY/h
Organic matter:				MAFF (2008)
Price of organic matter	C_{op}	5 000	JPY/t	
Transportation cost	C_{ot}	1 000	JPY/t	
Spreading cost	C_{os}	2 000	JPY/t	
Other cost:			JPY/10a	MAFF stat. (2008)
Rice	O_1	62 267		
Wheat	0_2	43 972		
Monetary valuation:				
N removal benefit		6 563	JPY/kg	Shiratani *et al.* (2004)
N runoff damage		650	JPY/kg	Shiratani *et al.* (2004)
GHG damage		7 039	JPY/t	Baker *et al.* (2007)

Source: Author's compilation.

Notes

1. The following are the main functions of irrigation water in paddy: 1) natural supply of nutrient, 2) nitrogen fixation, 3) accumulation of organic and easily-absorbed and 4) less soil erosion.
2. Suppose that the N content in organic fertilizer is not included in this equation, because N in organic fertilizer could be serious problem only when the application amount is enormous. In this model, the maximum of organic is approximately 1.5 t/10 ares due to the economic reason (high additional cost).
3. This function is estimated by Dr Shiratani at National Institute for Rural Engineering as one example.
4. For example: Shiratani (2004) estimates as [N runoff(kg/10a)] ＝**0.317*** [the amount of N application]+0.5887, and Takeda (1997) estimates as [N runoff (kg/10 ares)] ＝**0.281*** [the amount of N application]+1.33
5. Calculations based on *2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry and Other Land Use* (IPCC, 2006) and "National Greenhouse Gas Inventory Report of Japan" (MOE, 2008), as far as possible.
6. See also Ministry of the Environment Greenhouse Gas Inventory Office of Japan [GIO], CGER, NIES (2008) for detailed information (www-gio.nies.go.jp/aboutghg/nir/2008/NIR_JPN_2008_v4.0_E.pdf).
7. General emission factors which are used here are estimated by the Secretariat from CH_4 emission factors on each soil type and the proportion of Japan's surface area by soil types.
8. The exponent in this equation is provided with uncertainty range of 0.54-0.64.
9. The emission factor of Japan is lower than that of default value in the IPCC (2006). It is the reason that the volcanic ash soil that is widely distributed in Japan releases little N_2O emissions.



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